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Runoff and Sediment From a Burned Sagebrush Community[1]

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Abstract.—A sagebrush/juniper community was burned at different fire intensities to determine runoff and sediment yields. Runoff was similar between unburned and low intensity burns but almost 4 times greater from high intensity burns. Low intensity burns produced twice the sediment of the unburned. High intensity burning produced 5 times the sediment of the unburned.

Prescribed burning is used on rangelands to: (1) reduce fuel load (2) improve range condition, (3) increase forage, (4) improve wildlife habitat and, (5) increase localized water yield. Fire affects many facets of the natural ecosystem. Watershed response to burning depends on vegetation type (Wright 1974), fire intensity, topography and soils (Rice 1973), season of burning (McMurphy and Anderson 1965), and probably most importantly, climate conditions following the burn. Burning can increase both water and sediment yields on pinyon/juniper dominated rangelands (Roundy et al. 1978) and on chaparral dominated rangelands (Hibbert et al. 1981). Other studies indicate no increase in runoff or sediment from burning mesquite *(Prosopis glandulosa)* or whitebrush *(Aloyisa lycoides)* rangelands and post oak *(Quercus stellata)* savannahs in Texas (Garza and Blackburn 1985, Knight et al. 1983). Researchers have evaluated the hydrologic effect of mechanical and chemical treatments of sagebrush dominated rangelands (Blackburn and Skau 1974, Gifford 1982, Lusby 1979). However, the hydrologic and erosion responses of sagebrush burning have not been evaluated.

This study, as part of the USDA Agricultural Research Service's (ARS) Water Erosion Prediction Project, was to determine runoff and erosion from different aged burns, under two fire intensities, in a sagebrush/juniper vegetation community in northern California.

[1]Poster paper presented at the conference, Effects of Fire in Management of Southwestern Natural Resources (Tucson, AZ, November 14-17, 1988).

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EXPERIMENTAL DESIGN

Study Site Description

The study site, located in the USDI-Bureau of Land Management's (BLM) Eagle Lake Resource Area in the Susanville District in northeastern California, is typical of the Great Basin sagebrush/juniper vegetation type. Major woody species include big sage *(Artemesia tridentata)*, western juniper *(Junipererus occidentalis)*, bitterbrush *(Purshia tridentata)*, and desert gooseberry *(Ribes velutinum)*. Perennial grasses include Idaho fescue *(Festuca idahoensis)*, western needlegrass *(Stipa occidentalis)*, and squirreltail *(Sitanian hystrix)*. The soil is a Jauriga gravelly sandy loam which is a fine-loamy, mixed, mesic Typic Argixerol with about 35% gravel. The climate is characterized by cold, snowy winters and hot dry summers. Average annual precipitation is 355 mm with 30% occurring during the growing season and 70% as winter snow. The plant growing season begins in early May and continues until mid-July when soil moisture is usually depleted. Livestock grazing is the major land use and the study site had been excluded from grazing one year before and during the study period.

Procedures

Runoff and erosion were measured from plots (10.7 x 3.05 m) under simulated rainfall conditions. Troughs at the lower end of each plot diverted water and sediment into runoff measuring flumes and the hydrograph was recorded by water level recorders. Sedigraphs and sediment yields were determined from periodic water/sediment aliquots taken at the flume's exit.

Rotating-Boom Rainfall Simulator

A trailer mounted rotating boom rainfall simulator (Swanson 1965) was used to apply water to the plots. The simulator has ten 7.6 m booms radiating from a central stem (figs. 1 and 2). The booms support 30 V-Jet 80100 flow-regulated nozzles positioned at various distances from the stem. The nozzles spray continuously downward from an average height of 3 m, move in a circular path over two plots, apply rainfall intensities of about 65 or 130 mm/hr and produce rainfall energies of 900-1250 MJ*mm/ha*hr. Rainfall spatial distribution over each plot has a coefficient of variation of less than 10%.

Rainfall Simulation Run Sequence

Rainfall simulations were made on three soil moisture conditions. The dry soil surface run (60 min at 65 mm/hr rainfall rate) was followed 24 hours later by the wet run (30 min at 65 mm/hr rainfall rate) which was then followed 30 min later by the very wet run which had varying rainfall intensity (65 and 130 mm/hr). This sequence provides runoff and sediment data for unsaturated (dry run), field capacity (wet run) and saturated (very wet run) soil moistures.

Treatments

There were 2 natural (undisturbed), 1 clipped, 1 bare, 2 fall 1986 burned (Burn-86), and 2 fall 1987 burned (Burn-87) plots. All the plots were grouped within a 50 by 50 m area with the same soil and vegetation type. The clipped treatment had all vegetation cut to 2 cm height and the clippings removed from the plot. This treatment was used to evaluate plant canopy effects on runoff and erosion and not intended to show grazing effects. The bare treatment had all vegetation clipped to the ground surface and all surface cover (litter, rock and gravel) removed with minimal soil surface disturbance. The Burn-86 plots were burned in the fall of 1986 using a low intensity fire to simulate a prescribed burn followed by overwinter snowpack and high intensity rainfall. The Burn-87 plots were fall burned in 1987 using a high intensity fire just prior to the 1987 rainfall simulations. This burn was to simulate wildfires that are followed by high intensity rainfall. Rainfall simulations were made after plot treatments in the fall of 1987 and again in the spring of 1988 when the clipped and bare plots were retreated. The Burn-86 plots were not reevaluated in 1988.

Vegetation and Plot Characteristics

A 49 pin-point meter was used to measure vegetation composition, canopy cover and height, and ground cover of each plot. Ground cover characteristics included: soil, gravel (5-20 mm), rock (> 20 mm), litter, and basal plant cover. Ten transects across each plot produced 490 readings to describe surface and vegetation canopy cover. Soil moisture content (percent by weight) at 0-5 cm was determined before the dry and wet runs and after the very wet runs.

RESULTS

The plots runoff and sediment yield responses are biased toward exceptional natural rainfall events because during a simulation run each plot was subjected to 1 to 2.4 times the annual rainfall energy for the site (290 MJ*mm/ha*hr). The total rainfall energy applied to each plot during a year's evaluation was nearly 5 times the natural average annual energy.

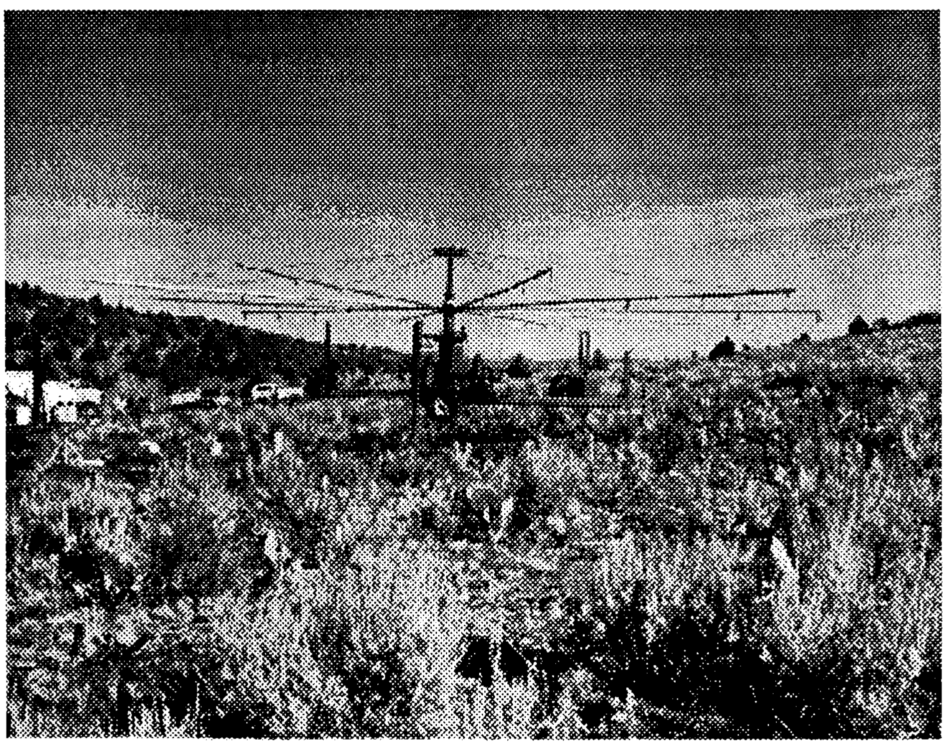

Figure 1.—Rotating boom rainfall simulator at the study site.

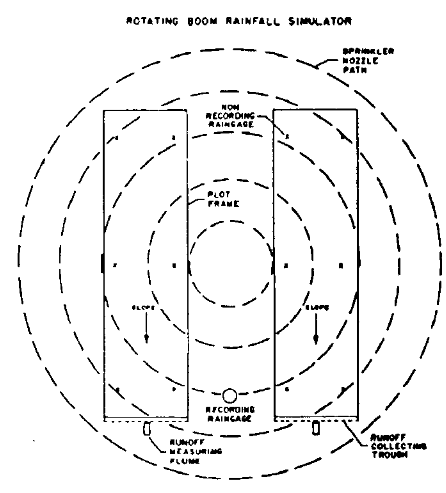

Figure 2.—Schematic of plot layout.

Plot surface and canopy cover characteristics for 1987 and 1988 are presented in table 1. The reason for the changes between the 1987 and 1988 vegetation canopy cover is difficult to explain because of differences in season of measurement. Compared to the natural plots' vegetation composition trend, there was a reduction in the shrub canopy cover component associated with the 1986 and 1987 burns.

Table 2 presents the rainfall, runoff and sediment yield results for all rainfall simulation runs. Runoff and sediment from the natural and clipped plots were similar at all soil moisture conditions. Runoff and sediment yield variability between plots of the same treatment cannot be explained by differences in measured ground or canopy cover. The variablity may be a function of cover distribution on the plot and/or soil variability; factors very difficult to statistically evaluate in natural environments. Because of the small number of plots used in this study, statistical analysis between treatments could not be made.

Sediment yields per mm of runoff from the natural plots were 2 times greater in the fall than in the spring. In contrast, Simanton and Renard (1981) found natural plot sediment concentrations from rainfall simulation studies in shrublands of southeastern Arizona were about 2 times higher in the spring than in the fall.

For each simulation run, the average of each treatment's runoff and sediment yield was divided by the total rainfall of that run. These runoff and sediment yield coefficients were then plotted as a function of soil moisture measured before the beginning of each run (figs. 3-6). Except for the bare treatment, runoff coefficients of the other treatments were similar under low soil moisture conditions (figs. 3 and 5). As soil moisture increased, runoff coefficients of all the treatments increased. The runoff coefficients of the natural, clipped and Burn-86 were similar at all soil moistures. At the very wet soil moisture condition, the runoff coefficient of the Burn-87 treatment was almost 4 times those of the natural, clipped and Burn-86. The bare treatment runoff coefficient increased with soil moisture at a faster rate than the runoff coefficients of the other treatments and at the highest soil moisture condition was over 10 times the runoff coefficient of the natural treatment. This rapid increase of the bare treatment's runoff coefficient is probably a function of increased soil surface crusting and sealing.

The spring 1988 runoff coefficient for the 5-month old Burn-87 treatment was over 6 times the 1988 natural treatment runoff coefficient. Because the natural treatment and 1-yr old Burn-86 treatment had very similar runoff coefficients it appears that the hot burning treatment may either have a long term effect on the runoff response or that a complete growing season is necessary to overcome the fire effects.

Sediment yield coefficients showed trends similar to the runoff coefficients (figs. 4 and 6) with the largest sediment coefficients associated with high soil moistures. The sediment coefficients of the natural and clipped treatments were not different in the fall of 1987. However, in the spring of 1988, one of the natural plots was producing considerably larger amounts of sediment than the other natural and clipped plot. This illustrates the natural spatial variability associated with field sites. The bare treatment had the largest sediment coefficients, especially at high soil moisture (fig. 4). The increase in the bare treatment's sediment coefficient between 1987 and 1988 follows a similar time related trend found for bare plots studied in Nevada and

Table 1.—Vegetation and surface characteristics of runoff plots for fall 1987 and spring 1988.

	Ground surface cover (%)				Canopy cover (%)		
	Soil	Rock/ gravel	Litter	Basal	Grass	Forb	Shrub
Fall 1987							
Natural	14.7	9.0	64.1	12.2	4.9	3.3	21.2
Natural	16.7	16.3	53.5	13.5	4.5	1.6	18.4
Clipped	7.3	9.1	71.8	11.8	0.0	0.0	0.0
Bare	75.7	6.4	7.0	10.9	0.0	0.0	0.0
Burn-86	20.0	21.6	49.4	9.0	0.8	2.0	8.6
Burn-86	19.2	20.4	55.5	4.9	2.9	3.3	8.2
[1]Burn-87	21.2	3.9	51.4	13.5	7.8	1.6	16.3
[1]Burn-87	14.3	18.4	53.1	14.3	7.8	4.1	17.1
[2]Burn-87	40.5	43.3	10.6	0.0	0.0	0.0	0.0
[2]Burn-87	45.0	48.9	11.7	0.0	0.0	0.0	0.0
Spring 1988							
Natural	16.4	14.5	57.7	11.4	13.2	3.6	15.0
Natural	16.4	17.7	55.9	10.0	9.5	1.8	17.3
Clipped	13.2	9.5	70.5	6.8	5.9	0.5	0.0
Bare	66.8	13.6	10.0	9.5	0.5	1.4	0.0
Burn-87	30.0	33.6	33.6	5.5	9.5	4.1	0.0
Burn-87	40.0	27.7	28.2	4.1	7.7	8.6	0.0

[1]Before burn

[2]After burn

Arizona (Simanton and Renard 1986). Sediment coefficients of both burned treatments were higher than the natural or clipped treatment. At the highest soil moisture condition, the Burn-86 sediment coefficient was about 2 times the natural's. Under similar high soil moistures, the Burn-87 sediment coefficient immediately after burning was 5 times the natural's. Five months after the burning the sediment coefficient of the Burn-87 was 16 times the natural's. In contrast, the sediment coefficient of the bare treatment under the high soil moisture condition was 28 times the natural's in 1987 and almost 220 times greater in 1988 (fig. 4).

CONCLUSIONS

The burning treatments increased runoff and sediment yields from extreme rainfall events on wet soil. Burning will not increase runoff or sediment yields from normal rainfall events when the soil moisture is less than field capacity. Rainfall events occurring on very wet soil, which can occur in early spring, may produce increased yields from burned areas, especially those burned by high intensity fires.

The BLM's policy of prescribed fall burning, using a low intensity fire, appears to be suited for the vegetation community evaluated in this study. The prescribed burning reduces the hazard of wildfires by removing shrub species and accumulated litter and has little effect on surface runoff and sediment yields.

Table 2.—Rainfall, runoff, and sediment from erosion study plots for dry, wet, and very wet soil moisture conditions for fall 1987 and spring 1988.

Treat.	Fall 1987			Spring 1988		
	Rainfall *(mm)*	Runoff *(mm)*	Sediment *(kg/ha)*	Rainfall *(mm)*	Runoff *(mm)*	Sediment *(kg/ha)*
			Dry			
Natural	56.1	0.0	0.0	43.7	0.0	0.0
Natural	57.3	0.2	11.6	44.6	0.2	4.7
Clipped	55.1	0.0	0.0	42.2	0.0	0.0
Bare	58.1	4.2	196.0	43.9	7.8	657.2
Burn-86	42.9	0.5	46.4	—	—	—
Burn-86	44.2	0.1	5.3	—	—	—
Burn-87	33.5	0.1	0.0	41.4	0.1	0.6
Burn-87	33.9	1.0	73.2	45.8	0.6	19.3
			Wet			
Natural	24.0	0.4	11.3	23.2	0.1	1.1
Natural	23.4	0.2	17.1	24.6	0.8	19.7
Clipped	26.2	0.4	17.9	22.4	0.1	1.0
Bare	24.9	8.0	[1]500.0	25.2	12.8	3013.3
Burn-86	24.2	0.4	32.3	—	—	—
Burn-86	25.7	0.2	13.0	—	—	—
Burn-87	28.0	1.0	110.4	26.9	2.0	188.2
Burn-87	25.7	2.0	171.1	27.5	2.0	135.5
			Very Wet			
Natural	34.8	1.8	79.2	45.7	0.1	4.8
Natural	26.1	0.7	97.7	27.4	1.3	48.2
Clipped	27.9	1.0	86.1	24.4	0.3	8.7
Bare	28.6	13.7	2369.0	24.9	14.7	4256.1
Burn-86	25.9	1.7	188.8	—	—	—
Burn-86	27.6	0.6	82.5	—	—	—
Burn-87	33.2	3.9	407.5	29.6	6.3	651.2
Burn-87	35.8	5.3	502.6	29.7	5.3	280.9

[1]*Estimated*

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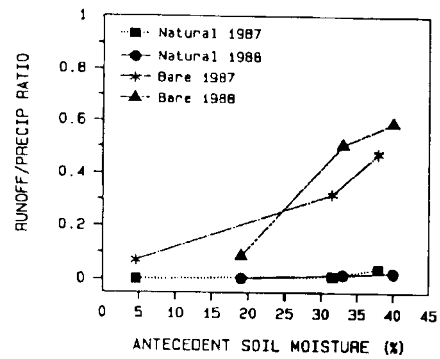

Figure 3.—Antecedent soil moisture vs. runoff/precipitation ratio for the 1987 and 1988 natural and bare plots.

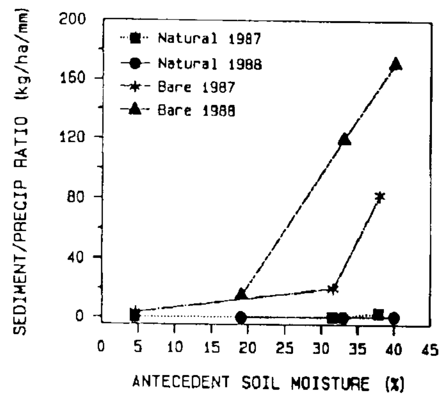

Figure 4.—Antecedent soil moisture vs. sediment/precipitation ratio for the 1987 and 1988 natural and bare plots.

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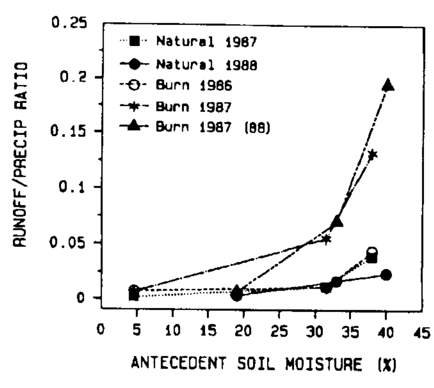

Figure 5.—Antecedent soil moisture vs. runoff/precipitation ratio for the 1987 and 1988 natural and burned plots.

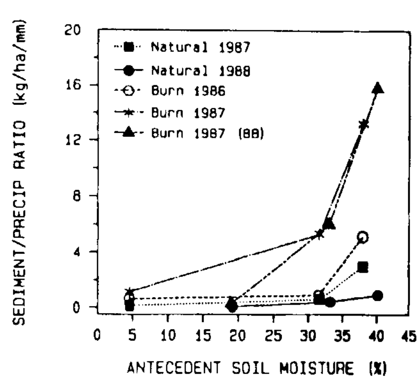

Figure 6.—Antecedent soil moisture vs. sediment/precipitation ratio for the 1987 and 1988 natural and burned plots.

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